Draft Internal Assessment Resource
For planning purposes only

Draft standard 2.1: Carry out a practical physics investigation that leads to a non-linear mathematical relationship

Resource reference: Physics 2.1A

Resource title: Distance and time

Credits: 4

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Not for use with students
in 2011

Teacher guidelines

The following guidelines are designed to ensure that teachers can carry out valid and consistent assessment using this internal assessment resource.

Teachers need to be very familiar with the outcome being assessed by Achievement Standard Physics 2.1. The achievement criteria and the explanatory notes contain information, definitions, and requirements that are crucial when interpreting the standard and assessing students against it.

Context/setting

This assessment requires students to take measurements, use techniques to maximise accuracy, analyse the collected data, and develop the equation that models a non-linear physical relationship.

Because of the detailed evidence given in the schedule, the experiment on which this activity is based cannot be used for assessing the standard. The activity must be adapted to another context and experiment that presents similar opportunities to meet the standard.

In this example investigation, students determine the relationship between downhill rolling distance and time.

Students record and graph data, transform the graph, use the transformed graph to find the mathematical equation relating distance and time, and produce a report which evaluates and explains the results.

Conditions

The investigation is to be performed in-class under supervised conditions, over a continuous period of 3 hours; each student should gather and evaluate their own set of data, and produce their report independently.

Conclusions must be written; confirm the format of the report with your students. The format could be, but is not limited to a written report, computer presentation software or web page.

Analysis can be done manually, via graphing calculator, or via a computer, but the analysis must be able to be stored by the assessor or printed for marking purposes.

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Resource requirements

Students will need a ball, a timing device, and suitable equipment to create a defined angle slope with consistently measurable distances, for example:

- metre rulers with channel/track down the centre of one side
- marbles or other suitable rolling ball
- stopwatches
- clamp stands, clamps and bosses
- protractors.

Customise the student instructions as necessary, based on the equipment provided.

Additional information

None.

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Achievement	Achievement with Merit	Achievement with Excellence
Carry out a practical physics investigation that leads to a non-linear mathematical relationship.	Carry out an in-depth practical physics investigation that leads to a non-linear mathematical relationship.	Carry out a comprehensive practical physics investigation that leads to a non-linear mathematical relationship.

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Student instructions

Introduction

Inflatable globe riding is the sport of rolling down a hill inside a giant inflatable ball. John and Marama tried freestyle inflatable globe riding during the summer holidays. They enjoyed it so much that when they got back to school they decided to find out about the relationship between distance travelled down the slope, d, and time taken, t.

In this activity, you will prepare a report describing the relationship between the distance travelled down the slope, d, and time taken, t.

You will use a meter rule with a single channel in it as the constant slope and a rolling ball as the rolling globe.

Task

Working **independently**, you will be given a period of 3 hours to collect data, carry out the analysis of the data and write a report. The report should be handed in at the end of the assessment period. Confirm the format of the report you will be producing with your teacher, for example, it could be a written report, a poster or computer presentation. No material is to be taken from the laboratory.

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Gathering information

Using the equipment provided by your teacher set up the apparatus shown:

1 metre ruler with channel down the centre of one side

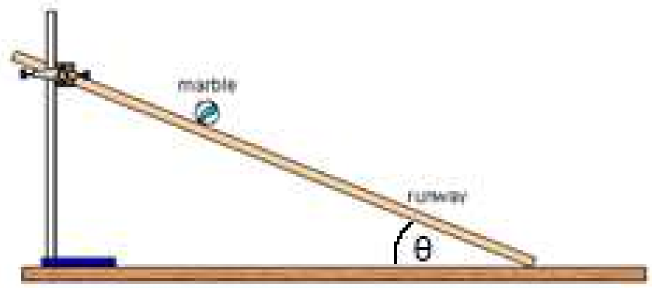
1 metre ruler

marble

stopwatch

clamp stand, clamp and boss

protractor



Investigate the relationship between distance travelled down the ramp, d, and time, t, for a rolling ball.

As you gather information, you should:

- identify the dependent and independent variables in the investigation
- identify any variables to be controlled
- record **all** raw measurements in an appropriately headed results table, using appropriate units and significant figures
- make sufficient measurements to allow you to draw a graph that will help you determine this relationship
- adjust your method as necessary to maximise accuracy.

Data analysis

Plot an appropriate graph to explore the mathematical relationship between distance travelled down the slope, d, and time, t. Include a curve of best fit (the raw data will not give a straight-line graph.)

The distance travelled down the slope, d, and time, t, are not proportional variables. Decide the type of relationship that this graph suggests.

Process the data so that you can draw a straight-line graph. Plot and draw the straight-line graph.

Using information from the straight-line graph find and state the mathematical relationship between distance travelled down the slope, d, and time, t.

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Producing a report

Write a report that evaluates and explains the results of your investigation. Your report should include:

- the dependent and independent variables of your investigation
- the techniques you used to improve the accuracy of your investigation
- an appropriately headed table which records **all** raw measurements using appropriate units and significant figures
- the non-linear graph you have drawn
- the relationship that the non-linear graph suggests between the variables of distance travelled down the slope, d, and time, t, for the investigation
- an appropriately headed table which records processed data using appropriate units and significant figures
- the linear graph you have drawn
- a conclusion that states the correct mathematical relationship between the distance travelled down the slope, d, and time, t, based upon the linear graph
- a discussion that validates the conclusion.

You may validate your conclusion using one or more of the following:

- identification of any variables that you controlled, an explanation of why they should be controlled and how you controlled them in your investigation
- a description of any difficulties encountered when making measurements and an explanation of how these difficulties were overcome
- a reason why there was a limit to the range of values you chose for the independent variable
- an identification of any unexpected results and a suggestion of how they could have been caused or the effect they had on the validity of the conclusion
- the relationship between the findings and physics ideas.

Additional Information

Physics theory states that, for an object with uniform acceleration, the following equations apply:

$v_f = v_i + at$, $d = v_i t + \frac{1}{2}at^2$, $v_f^2 = v_i^2 + 2ad$, $d = \frac{1}{2}(v_i + v_f)t$

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Assessment schedule: Physics 2.1A Distance and time

Evidence/Judgements for Achievement	Evidence/Judgements for Achievement with Merit	Evidence/Judgements for Achievement with Excellence
Student correctly: • identifies the independent (time) and dependent (distance) variables • gathers at least 5 values of distance (d) and time (t), over a range of at least 0.600 metres, using the smallest scale division of the measuring instrument • plots points on a graph showing the relationship between the independent and the dependent variables, on axes labelled properly with quantities and units, and including a curve of best fit • describes the type of relationship that exists between d and t, with correct proportionality of variables, d α t^2. Accept alternative non-linear graphs that lead to the correct relationship. For example, a student who *achieved* may provide information similar to the following: *The graph below shows the relationship between distance and time. The distance the ball rolled depended on time. I recorded seven different distance-time points on a constant slope (I used an angle of 15 degrees throughout), to the nearest half second and millimetre; I found that the relationship was quadratic, with distance being proportional to the square of time.*	Achievement plus student correctly: • states or implies control of the angle of ramp variable • uses techniques to improve the accuracy of the measured values, for example, repeats and averages three measurements for a particular distance, corrects for parallax by lining up eye with end of ruler to accurately stop timer, or adjusts the slope angle to produce a more suitably measurable range of times • transforms values of t to t^2, with appropriate significant figures and units of t^2 (likely to be 3 significant figures of s^2, depending on the measuring instrument used) • plots non-linear and linear graphs showing the relationship between the independent and the dependent variables, on axes labelled properly with quantities and units, and including lines of best fit • calculates the gradient of the linear graph • derives the mathematical equation from graph, d = gradient x t^2 (value of gradient to be consistent with student data). Accept alternative linear graphs that lead to the correct equation. For example, a *merit* student may provide information similar to the following: *The graphs below show the relationship between distance and time. The distance the ball rolled depended on time. I measured about twenty different distance-time points on a constant slope (I tried*	Merit plus student makes a good attempt at two, or a reasonable attempt at three of the following: (Note: The discussion statements given by a student do not necessarily have to be 100% correct but they must be reasonable considering the knowledge the student is expected to have.) • justifies their choice of the ramp angle size, for example, a larger angle makes the time too short to be measured accurately by a stopwatch • justifies their choice of the range for the independent variable, for example, because of a limit to either end of the values chosen for the independent variable • describes the difficulties encountered when measuring, and links them to techniques used to improve the accuracy of the measured values, for example, notes that human reaction times can be slower than $1/10^{th}$ of a second and therefore repeats and averages three time measurements for a particular distance to reduce reaction time error • reflects on the validity of their conclusion, with respect to physics ideas, unexpected outcomes, and/or effects of their particular experimental method. For example, an *excellence* student may provide a discussion similar to the following: *I measured about twenty different distance-time points on a constant slope, starting from 0.1 metre as distances less than 0.1 metre were too short to measure without reaction time becoming a large factor compared to the time measured. I also initially had*

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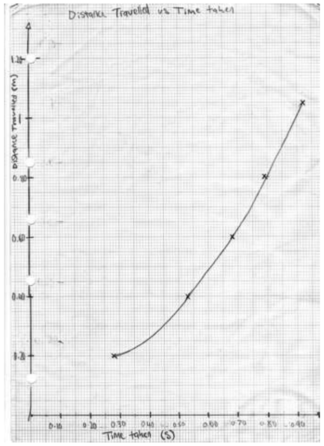
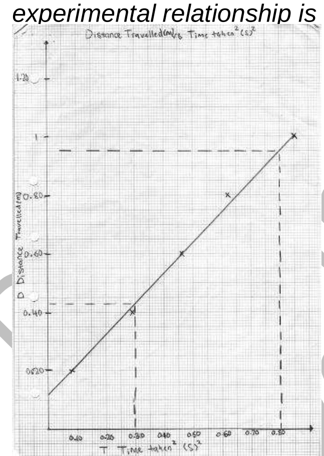
	*different angles, and found that 15 degrees gave me a consistent set of measurements.) I plotted the average of three trials for each distance to improve accuracy. I found that the relationship was quadratic, with distance being proportional to the square of time. I then transformed my data and plotted a graph of d vs.* t^2*. As you can see, the* t^2 *graph is linear, with a gradient of the line of best fit of about 1.0, so my experimental relationship is* $d = 1.0t^2 + 0.12$*.* 	*difficulty measuring time as my high angle meant that the ball rolled faster than I could react. I lowered the angle to 15 degrees, at which point I could get a consistent set of measurements. I then kept the angle constant (controlled) to avoid introducing a second variable of slope into my experiment. It was hard to measure time accurately because I had to make a judgement each time I started and stopped the stopwatch. As the inaccuracy was random (just as likely that the time was too short as too long), I plotted the average of three trials for each distance to improve accuracy; I ignored the highlighted outliers on the graph at the lowest distance values because even with averaging, reaction times played a large factor, as you can see from the big variation in my raw data. I found that the relationship was indeed quadratic. I know this because when I transformed my data and plotted a graph of d vs.* t^2*, my graph was linear, with a gradient of the line of best fit of 1.0. However, there was an unexpected intercept which indicated that it takes zero time to travel 12 cm which is clearly impossible. I think this error could be because my technique for starting and stopping the stopwatch was such that the inaccuracy was not random but gave an error that meant all times were a bit too short. I decided it would be valid to ignore this error, so my experimental relationship is* $d = 1.0t^2$*. The constant acceleration equation* $d = v_i t + ½at^2$ $(v_i = 0)$ *means that* $d = ½at^2$ *and so* $½a = 1.0$ *or* $a = 2$*. As the ball accelerates down the slope because of gravity should be the component of gravity down the slope.* $a = g\sin\theta = 10 \times \sin 15° = 2.6$*. The actual acceleration is a bit less than theory predicts so friction could be slowing the ball down. Or it could be that the angle was not accurate– it was hard to measure the angle of the metre stick, and the stick had a slight bow. However the angle would have had to be 12° to give the predicted acceleration, so perhaps it was a bit of both.*

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Final grades will be decided using professional judgement based on a holistic examination of the evidence provided against the criteria in the Achievement Standard.